BULL. BOT. SURV. INDIA
Vol. 21, Nos. 1-4 : pp. 28-34, 1979

SPIRAL MECHANISM IN *ARENGA PINNATA*

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ABSTRACT

The phyllotaxy of *Arenga pinnata* is alternate and cyclic revealing two distinct foliar spirals. In some individuals, the two spirals veer to the left and in others, to the right. The number of leaflets on one half of leaf differs from that of the other. This difference is associated with the leaf spirals. Due to the monocarpic nature of the palm, its reproductive phase starts with a terminal inflorescence followed by the development of axillary inflorescences in basipetal order. The sex of the flowers varies with the position of the respective spadices on the palm. That is, the terminal and a few immediate successive spadices produce only female flowers, beyond which each inflorescence produces both female and male flowers, and the last many spadices have only males. The flowers are distributed in clusters of 2 males or 2 males and a female in between, or individually if they are only females. In a cluster of 2 or 3 flowers, the aestivation of sepals of the males varies with their position in the triad. The aestivation pattern in female flowers, however, has an influence on the spirality of the spikes on which they are borne.

INTRODUCTION

The alternative phyllotaxy in palms leads to spiral patterns in the structure of their vegetative organs (trunk and leaves), reproductive organs like spadices, spikes, flowers, perianths and carpels. As the leaves are arranged cyclically, the spirals they display become easily perceivable in most species. The foliar spirals (Plate I, fig. 1) may move clock-wise (left-handed) or counter-clockwise (right-handed), but the number of spirals for a species is constant. Moreover, the spiral number in any species always synchronises with a term of the Fibonacci Sequence (Davis, 1970, 1971).

The spiral mechanism in palms has been studied by Davis & Kundu (1966), Davis & Basu (1971) and Davis, Ghosh & Mitra (1971). The kind of spirality in palms is found to be of random occurrence although some possibility of geophysical influence on such a spirality is suspected (Davis, 1964). The type of spiral pattern occurring in a particular organ of a palm (leaves, flowers or perianths) does not necessarily resemble that of another. It is still unknown how the factor actually governs the spiral pattern in different organs of a palm.

The spiral system is very conspicuous in *Arenga pinnata* commonly known as the sugar palm of Indo-Malayasian origin. The palm belongs to Caryotoid group which is characteristic of its monocarpic habit. The object of the present study is to find out how the spiral pattern is manifested in this species in its vegetative and reproductive structures, and also to understand the interrelationship among the different parts of a palm.

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Date of receipt: 11.8.77. Date of acceptance : 2.11.79

MATERIALS & METHODS

Arenga pinnata (Wurmb.) Merrill is single-stemmed; stem erect and covered with triangular sheathing leaf bases having a network of black horse-hair like fibre. Leaves are pinnate, 650-700 cm long and subtended by long petioles. Leaflets are sub-sessile and linear with auriculate base. Primary inflorescence is terminal followed by the development of axillary inflorescences in a basipetal order. Each inflorescence has a short peduncle covered with 6-10 tubular spathes, and many flower bearing spikes develop from a short rachis. Each spike bears numerous clusters of 3 flowers each (triads), a female in between two males, or twin males or rarely only single males. The terminal spadix bears only single females. Flower clusters are spirally arranged on the spikes (Plate I, fig. 2). The expression of functional male and female flowers is restricted to two different zones of the tree. The terminal inflorescence and a few others developed from the uppermost leaf axils bear functional female flowers and sterile male flowers. The female flowers gradually decrease in number and size at lower axils and disappear totally at still lower level. Simultaneously, the functional males start developing as the females become progressively smaller. Finally, the central flower (female) of the cluster fails to develop leaving the two side ones (male flowers) in each flower cluster. Very rarely the cluster may have only a single male flower (Plate I. fig. 3).

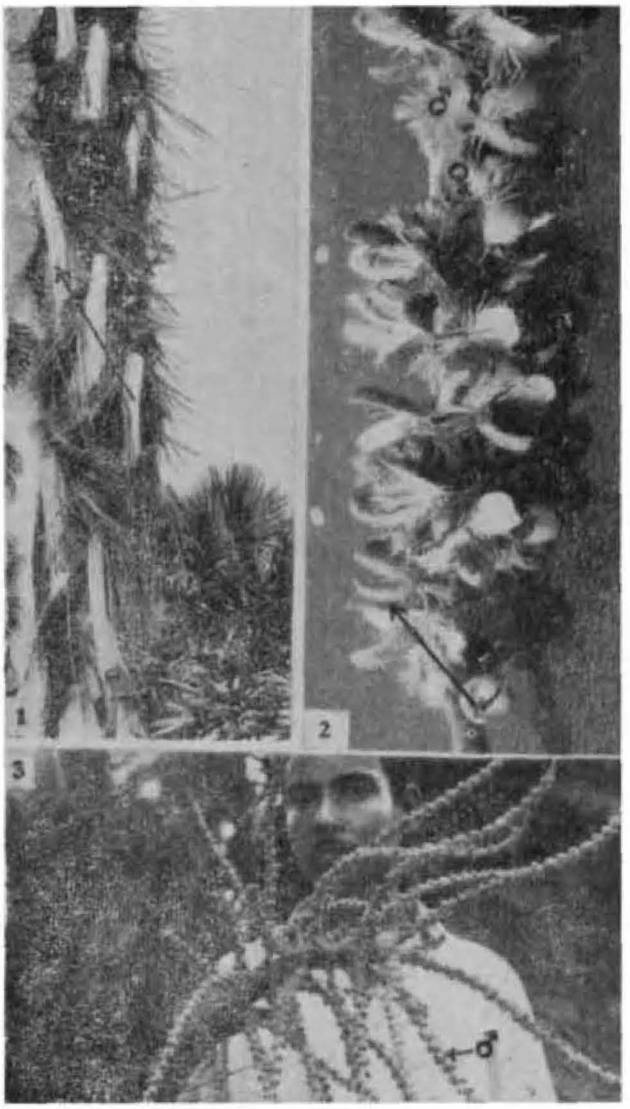


Plate I: Fig. 1. Stem of *Arenga pinnata* showing a distinct left spiralled foliar arrangement. Fig. 2. A spike with clusters of staminate and pistillate flowers in left spiralled arrangement. Fig. 3. Inflorescence with solitary staminate flowers on the spikes. Pistillate flowers missing.

Field observations were undertaken at the Indian Botanic Garden, Howrah during 1971 to 1975 on the phenology of *Arenga pinnata* palms growing at different localities of the garden. Five right-spiralled (for leaf arrangement) and five left-spiralled palms were selected. For examining the bilateral symmetry of leaves and their association with the foliar spirals, 3 leaves each from the left and right-spiralled trees were collected. The number of leaflets on each half was counted. Ten inflorescences were collected from different trees during different seasons. The spirality of each spike of the spadices was determined and the left and right-spiralled spikes were kept in two groups for the examination of the aestivation of flowers. The data are presented in the Tables 1 & 2.

Table 1: Number of leaflets on halves of leaves from left-spiralled tree

Leaf Number	Number of leaflets on left half	Number of leaflets on right half	L+R :	L−R
1	132	122	254	10
2	119	112	231	7
3	142	131	273	11
4	179	154	333	25
5	171	157	328	14
6	173	152	325	21
7	149	146	295	3
8	156	149	305	6
9	158	150	308	8
10	141	134	275	7
11	155	145	300	10
12	75	68	143	7
13	155	142	297	13
14	170	156	326	14
15	153	147	300	6
Total	2228	2065	4293	162

Number of spadix examined	Nubmer of spikes examined Left :	Right	Total
10	190	143	343

Table 2: Number of leaflets on halves of leaves from right-spiralled tree

Leaf Number	Number of leaflets on right half	Number of leaflets on left half	R+L :	R−L
1	154	153	307	1
2	162	153	315	9
3	162	154	316	8
4	75	74	149	1
5	82	80	162	2
6	162	152	314	10
7	149	137	286	12
8	151	145	296	6
9	146	142	288	4
10	147	135	282	12
11	115	105	220	10
12	149	138	287	11
13	145	136	281	9
14	140	133	273	7
15	135	125	260	10
Total	2084	1962	4046	112

Table 3: Aestivation of sepals in female flowers in relation to spirality of the spike

No. of spikes	Spirality of spike	Aestivation of sepals in female flowers								TOTAL
		LI	RI	L	R	RI-LI	LI-RI	R-L	L-R	
1	Right	7	32	—	—	25	—	—	—	39
2	„	17	32	—	—	15	—	—	—	49
3	„	12	50	—	—	38	—	—	—	62
4	„	2	27	—	—	25	—	—	—	49
5	„	37	61	—	—	24	—	—	—	98
6	„	7	46	—	—	39	—	—	—	56
7	„	18	38	—	—	20	—	—	—	53
8	„	29	80	—	—	51	—	—	—	109
9	Left	44	5	—	—	—	39			49
10	„	29	6	—	—	—	23			35
11	„	43	9	—	—	—	34			52
12	„	35	4				31			39
13	„	86	30				56			116
14	„	81	40				41			130
15	„	89	30				59			127
16	„	85	29				56			114
						237	339			1150

LI=Left imbricate, RI=Right imbricate, R=Right, L=Left.

OBSERVATIONS

Foliar asymmetry in relation to foliar spirals

In *Arenga pinnata*, out of fifteen leaves examined, the left half of leaves bore more leaflets than the right half. The difference between halves varied from 3 to 25. Out of a total of 4293 leaflets, 2228 were distributed on the left half and 2065 on the right. The data in Table 2 show that out of total of 4046 leaflets of right-spiralled trees, 2084 leaflets are on the right half and 1962 on the left. The difference between the halves of leaves varied from 1 to 12.

Spiral pattern in spikes

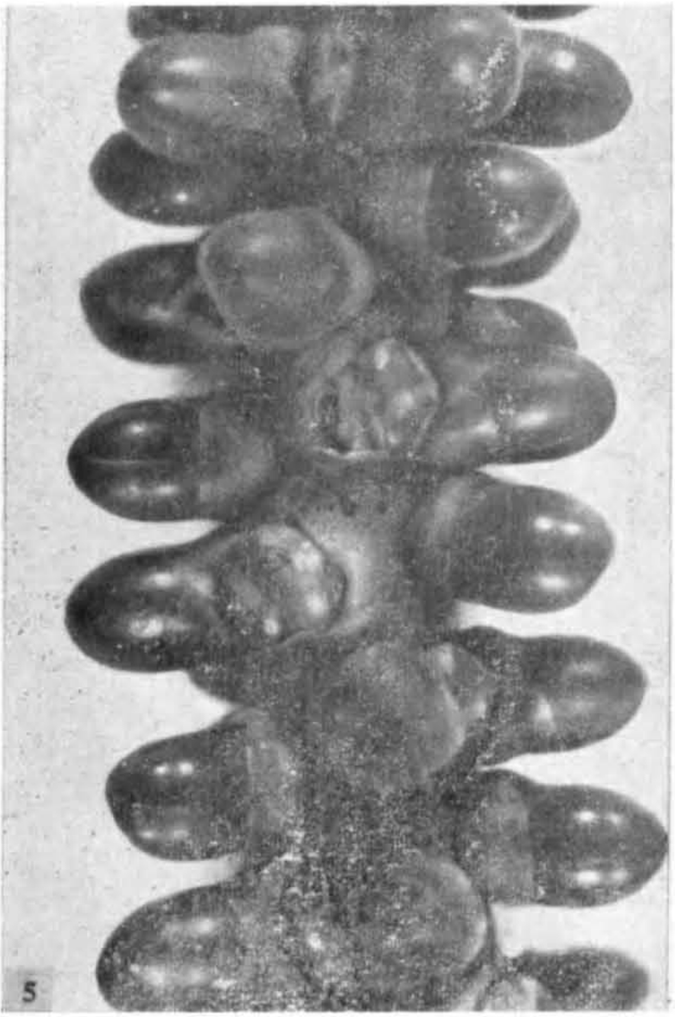
The spirality of a spike is determined from the position of consecutive flower clusters by holding the tip of the spike upward. Ten spadices from left and right-spiralled palms were examined. Out of 333 spikes, 190 were left-handed and 143 right-handed.

Aestivation of male flowers

The position of left and right male flowers in a cluster is determined by holding the tip of the spike upward. The female flowers, if present, are always in the centre. In some limited number of clusters, single male flowers and still rare, single female flowers were also observed. The male flowers of *Arenga pinnata* are club shaped, having imbricate sepals and valvate petals. Aestivation of the female flowers is also like that of the males. Here the left male flower of a triad shows left-handed imbrication and the flowers on the right has right-handed imbrication. To ascertain whether the spirality of spike has any relationship to the aestivation of male flowers in the cluster, 10 left and 10 right spikes were examined and the aestivation of the left and right male flowers was recorded. Plate II, figs. 4 & 4A show that in a majority of left male flowers the aestivation of sepals was left imbricate, and in the right males the sepals veered to the right. This pattern of aestivation in male flowers is followed throughout the normal spikes. In some, however, there are a few reversals at the base of the spikes. Out of a total of 2290 flower clusters examined from 20 spikes, in 94 percent of clusters the left males had left-imbricate sepals and the right males had right-imbricate sepals. This mirror-image condition in the male flowers is reduced at the lower-most portion of spike where some flower clusters remain irregularly placed. Some of them also show abnormal size.

Aestivation of sepals in female flowers

Out of a total 1150 female flowers examined from the right-spiralled spikes, the majority of the female flowers have right imbrication of sepals (Table-3), and



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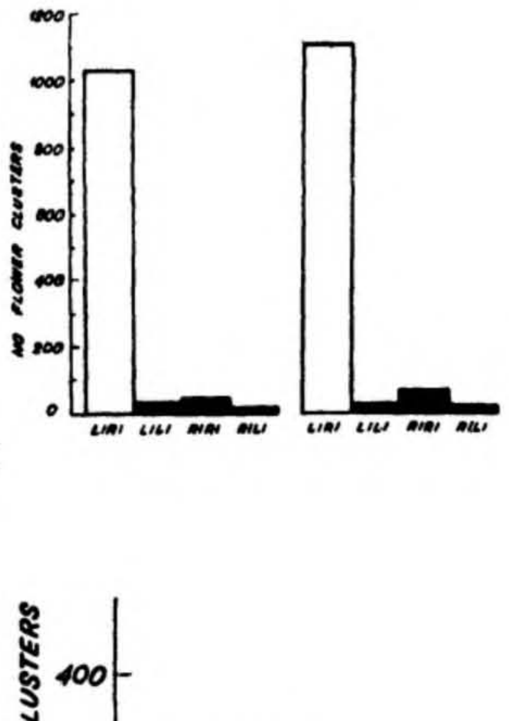

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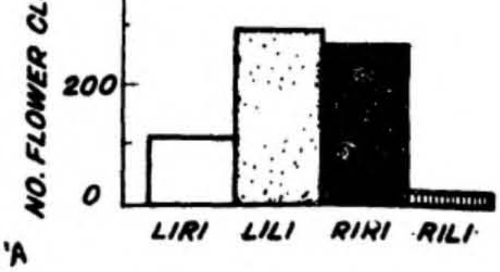

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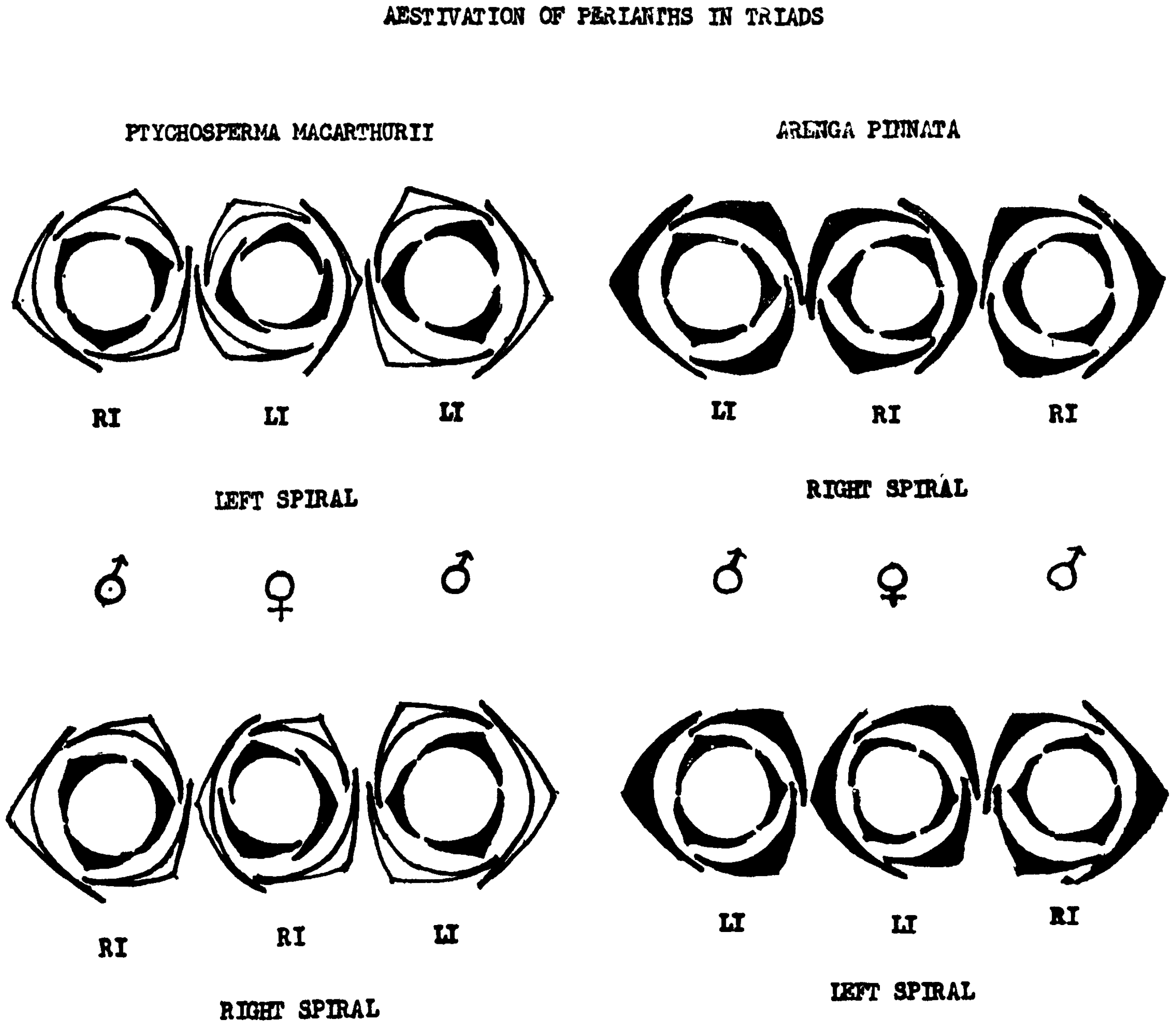
Plate II : Fig. 4. Aestivation of perianths in the left and right male flowers in triads of left-handed and right-handed spikes. Fig. 4A. Aestivation of perianths in the left and right male flowers under abnormal condition. **Fig. 5.** Triads in *Arenga pinnata*, showing each cluster in a line and perpendicular to the axis (spike).

in left-spiralled ones, the aestivation of sepals is more to the left.

DISCUSSION

Recent interest in the isomerism of plant organs has yielded interesting information regarding the asymmetric nature of plant organs. Due to the cyclic development of consecutive leaves, a definite spiral pattern becomes obvious in palms, whose possible relationship with other plant organs or fruit yield was not taken into account by earliar workers on palms. From their observation on fifteen species of palms, Davis *et al.* (1971) suggested that the number of leaflets on halves of leaves is associated positively with the foliar spirals. Pinnate leaves are more asymmetric than palmate or bipinnate ones, and this asymmetric nature is conspicuous in palms showing lesser number of foliar spirals. Our observation on *Arenga pinnata* having only two distinct foliar spirals confirm the above situation. Due to the monocarpic nature of this species its vegetative phase ends with a terminal inflorescence followed by the production of axillary inflorescences developed from the axils of lower leaves. The asymmetric nature of leaves actually conti-



Text fig. 1 : Schematic representation of typical triads in *Ptychosperma macarthurii* and *Arenga pinnata* showing opposite type of imbrication in left and right male flowers. RI—Right-handed imbrication of sepals. LI— Left-handed imbrication of sepals.

nued in the reproductive structure of the terminal inflorescence which is only the continuation of the main axis. The spirality of the spike is determined from the successive position of flower clusters on the axis and found quite distinct in the inflorescences developed from higher leaf axils.

The imbrication pattern of left and right male flowers in *Arenga pinnata* is totally reversed (Text fig. 1) from that of Arecoid palms like *Ptychosperma macarthurii* (Davis, 1974) and even in Caryotoid palms like *Caryota urens* and *C. mitis*. In all these palms, the aestivation of sepals in the left and right male flowers is in the reverse order of what is seen in *Arenga pinnata*. In *Ptychosperma* it has been reported from the ontogenic study of three flower cluster that the left-handedness and right-handedness of male flowers depends on the position of the first bracteole borne by the apex of the first male flower (Uhl, 1976). The first sepal (outer most) in the left and right male flowers remain opposite to each other (Plate II, fig. 5) for giving protection to the flower primordia. The direction of the subsequently developing sepals in both the flowers is responsible for fixing the imbrication pattern in the calyx of the male flowers. As the ontogeny of the flower cluster in *Arenga pinnata* has not yet been worked out, it is still unknown how the left and right male flowers in clusters show an oppposite type of imbrication deviating from the majority of other palms having similar flower clusters.

ACKNOWLEDGEMENTS

Authors are grateful to the Deputy Director, Indian Botanic Garden, Howrah and the Director, Botanical Survey of India, Howrah for providing facilities in the garden for palm studies. Technical service rendered by Shri C. C. Mukherjee of the Central Photographic Unit of the B.S.I. is gratefully acknowledged.

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